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CONTENTS

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THE TEACHING OF MATHEMATICS TO STUDENTS OF ENGINEERING [1]

FROM THE STANDPOINT OF THE PROFESSOR OF ENGINEERING

I feel that in this discussion we engineers occupy rather an unfortunate position, on account of the fact that we are compelled to assume the position of critics. The student comes to us from the teachers of mathematics, presumably equipped with a knowledge of that subject, and it becomes our duty to teach him subjects in which he makes use of this preparation, and to find out whether he has learned to use mathematics as a tool. However, I believe that only by friendly criticism can progress be made, and that every one ought to be willing to accept such criticism when given in the proper spirit. I had much rather be criticized than criticize others, and we teachers of engineering hope that we are always ready to receive suggestions, not only from other teachers, but from practising engineers.

I must first insist that for the engineer mathematics is to be regarded as a tool—not as something which is studied simply for the development of some mental powers, but for the ability which it ought to give a man to *do* something—to use the results and methods which he has been taught in solving the problems of his profession.

There has been a good deal of discussion in the past as to the value of mathematics simply as a means of mental training, without reference to its use, and perhaps most of us remember the paper by Sir William

[1] Continued from the issue of August 7.

Hamilton written seventy-six years ago, in which he maintains that there is no one of the subjects in the curriculum which develops a smaller number of mental faculties or develops them in a more imperfect and inadequate manner than mathematics. I have never seen what has seemed to me a conclusive refutation of Sir William Hamilton's main arguments, and for my part I am disposed to agree with him in general, and to assign a comparatively low value to mathematics simply as a training, aside from its applications. I have not observed that students trained in this subject are able *to reason* any better than students who have ignored mathematics; indeed, I believe that many non-mathematical subjects afford a better training in reasoning than the study of mathematics. This view may perhaps be justified by remembering that mathematics, aside from geometry, deals with questions of quantity and number, but not with questions of quality. The student puts certain fixed data into his mathematical machine and grinds out the result. He does not learn to observe and to discover the finer and more elusive, but equally important, sources of error likely to occur in the ordinary questions of daily life, because he is dealing with a rigid, unyielding, logical machine. In this way his mind may become hardened—he deals with rigid demonstrations and is unwilling or unable to appreciate or submit to a less rigid method, which is often the only possible one. The best student of mathematics is frequently one of the poorest of engineers. Give him fixed data and he will get the proper result, but he may be entirely incapable of attacking a practical problem, or of deciding what the proper data are.

I have not observed that students of mathematics are, as a rule, more *accurate* than other students, or that a training in the branches of mathematics above arithmetic leads to accuracy. Indeed, it more often appears to pervert the sense of perspective, and to lead students to work out a result to several figures in cases where a smaller number only may be significant. Mathematics does not train the *observation*, neither does it train the *imagination*, except in the geometrical branches, which are now comparatively neglected since the powerful modern methods in analysis have been introduced.

Hamilton only allowed, as I remember, that mathematics adequately trained one faculty, namely, that of *continuous attention:* but I fail to see that this is trained any better by the study of mathematics than by that of language, chemistry or by other natural sciences. Unfortunately, as at present taught it does train the memory, in a way that it ought not to do. The ordinary student of mathematics subordinates *perception* to a *memorization* of formulæ and rules.

I believe, therefore, that from the point of view of the engineer, mathematics should be taught with the object of giving the student power to use it as a tool. With reference to this I think it is fair to say that the consensus of opinion among engineering teachers and practitioners is that the results of the present mathematical training are very poor. The average student who has completed his mathematical course is frequently quite helpless when called upon to attack a concrete engineering problem, and it is a common remark by civil engineering students that they did not really learn any mathematics until they studied mechanics or the theory of structures. The results seem to be almost equally poor no matter what institution the student comes from, for in my classes there have been students from most of the principal universities and technical schools in the country and I have failed to notice any great difference in them in that respect.

They very generally lack the power to *do anything* with the mathematics which they have been taught.

With reference to the reasons for this state of things, I venture to state what seem to me to be some of them, and the suggestions which have occurred to me by which possibly the results might be improved.

1. In one of the previous papers a statement was made that many students who studied advanced algebra in the technical schools had not studied algebra in the preparatory schools for the two years previous. This illustrates what I believe to be one failing in our so-called system of education, namely, the lack of continuity. The remedy is to reform and simplify the curriculum, and to unify and simplify the entrance examinations to our colleges and technical schools. So long as these entrance examinations are so extended and cover so large a range of subjects, our preparatory schools will be unable to carry out their true purpose, which is, as it seems to me, no less and no more than that of all education, namely, to train a man *thoroughly* in a few things and to give him the power to do some little thinking for himself and to take up new subjects without assistance.

2. The great inherent difficulty which teachers of mathematics as well as teachers of every other subject meet with is the attitude of the student, and his inability to realize the seriousness and the importance of his work. I am fond of expressing my view in regard to this by the statement that the school is not a restaurant, but a gymnasium; not a place where a student comes to be filled up, but a place where he finds apparatus and the instruction, by making use of which he may strengthen his mental muscles.

The manufacturer can take his raw material and shape it into the form which he desires. The raw material of the teacher is the student, but the teacher can not take this material and shape it; he can only show it how it can shape itself. I believe, however, that much may be done in impressing upon students the proper attitude which they should take toward their work, and by a proper cooperation between teachers and parents, which is unfortunately lacking as a rule in this country, and the responsibility for which must largely fall upon the parents.

3. I believe that one cause of the poor results in mathematical teaching is that too great a stress is laid upon *analysis*. Mathematics is, of course, divided into geometry and calculus, using the words in their widest sense. Geometry is concrete; and the mind perceives the steps in a geometrical demonstration. This branch, the oldest branch of mathematics, however, has been largely supplanted by the modern analytic methods which have been developed during the past three centuries, largely to the detriment, it seems to me, of the educational results obtained. Analysis is abstract—it is a powerful machine, an invention for doing certain things. Into one end of the machine we put the data; we turn the crank, and the result comes out with absolute correctness so far as is warranted by the data. Now I believe that too much stress is laid on these analytical processes; that the student is not urged to visualize his results, to express them geometrically and to interpret his equations. I warmly second the remarks of Professor Ziwet with reference to descriptive geometry, which I believe should be treated as a branch of mathematics and taught more thoroughly, as it is taught in Germany. For my part, I derived as much benefit from my study of descriptive geometry, and afterward from the study of projective geometry, as from any other mathematical studies. These studies train

the imagination, which analysis does not do. But in the use of analysis, the first step, namely, the formulation of a problem, is really concrete. This, too, is neglected in our usual courses. Our examination papers are full of questions which involve simply the analytic processes—the differentiation, the integration, the twisting and turning of equations, while much less attention is paid to the formulation in mathematical language of practical problems. Our students, therefore, when they meet a practical problem, are unable to select or judge of the correctness of the data, and even if they can do this, are unable to formulate the data as a preliminary to the solving of the problem by the use of the mathematical machine.

One of the great defects which I find in students of mathematics is one already referred to, namely, that they do not *interpret their equations.* The average student who has completed his mathematical course, for instance, has not the slightest conception of what a parabola is. I make this statement advisedly, because I have tested it again and again for years. If he could tell you what a parabola really is in his mind, he would probably tell you that it was a curve of more or less beauty represented by letters. Perhaps he could tell you what the letters are, but give him a concrete problem and he would convince you immediately that he did not *know* what the letters mean.

4. Another defect, as it seems to me, in our present methods, is the lack of training in mental operations. In the good old days *mental* arithmetic was taught, but that seems to have gone out of fashion, with so many of the other good old methods. Ask the ordinary graduate of our mathematical courses to tell you the square of 20.75 without using pencil or paper and he will look at you open-mouthed with astonishment, but if he had really grasped the meaning of the binomial theorem and had learned to do a few "sums" in his head, any grammar-school boy would, of course, be able to give the result immediately.

5. Another reason for poor results is, I believe, inadequate class-room methods, and especially the use of the lecture system. In Germany, where the students in the universities have had the advantage of a thorough preliminary training, they may be able to appreciate lectures on mathematical subjects, although I doubt even this in the case of the average student. For students in our American universities, however, I believe that lectures in mathematics are almost useless, except for a very small number of students; and yet, I am told that even in some of our high schools mathematics is taught to a considerable extent by lectures. The lecture system is easy for the teacher. It involves no cross-questioning, no endeavor to discern what is going on in the student's mind, no adaptation of question with the object of putting him on the right track.

Again, some mathematical exercises are conducted by sending the students to the board, each with a problem to solve, and then marking that on the correctness of their work. Occasionally a formal explanation of his problem is required of the student. This, again, seems to me to be a mistaken method. Many a student can go through a demonstration of a principle, or solve a problem by substitution in a formula, while knowing nothing of the real meaning of the subject. In my opinion class-room instruction should be conducted by the Socratic method—by question and answer—the teacher endeavoring to put and keep the student upon the right track by showing him what he can do for himself if he will only learn how.

6. Reference has been made to the kind of teachers of mathematics. Personally I

believe that in teaching the subject to engineering students the best results would be obtained if the teachers were engineers, or at least if they were near enough to being engineers to take an interest *in the concrete problems themselves* as distinct from their solution. If I am correct in the belief that mathematics should be taught as a tool, then it can be taught best by those who know how to use it as a tool. Unfortunately, however, it is difficult to get engineers who are sufficiently interested in mathematics and sufficiently masters of that subject, who are willing to devote themselves to teaching. The men who are interested in the problems prefer to devote themselves to those problems, and to go into practical work. It is not necessary, however, as suggested above, that the teachers of mathematics should be engineers if only they will take an interest in the problems themselves, and in the point of view which the student should take. They can do this by cooperation with the engineering teachers, by attending engineering courses, and, perhaps, by a little more realization than they now have that their work is preliminary to other and more important work, and that as a matter of fact if the engineering student does not learn to use his mathematics as a tool it is practically of no value to him. For the engineer, mathematics is the servant, and the mathematical teacher should aim to teach the subject in such a way as to obtain as nearly as possible the results which intelligent engineering teachers and practitioners desire to have obtained.

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FROM THE STANDPOINT OF THE PROFESSOR OF MATHEMATICS IN THE ENGINEERING COLLEGE

We must not take too seriously what engineers have to say in an educational discussion, nor take too much to heart their views on the mathematical curriculum. Practising engineers are not in the habit of thinking very continuously on any educational question, although, of course, they must not confess inability to respond when they are called upon for pedagogical opinions. Every practitioner in the law would doubtless express views concerning legal education if summoned to do so, but he would be a rash educator who would attempt to follow their advice without much circumspection. I, myself, prefer to judge of the engineer's views upon educational matters by studying his actions rather than his words. The things engineers "do" may be taken as a true expression of their deliberate judgment—what they "say" is often ill thought out and in contradiction to their deeds. I therefore prefer to judge of the present needs in the mathematical instruction for engineers by the actual tendencies that I observe in the evolution of technology itself.

What are the great changes that the engineering profession has made in technical science in this country in the last quarter of a century? The changes are quite obvious and not difficult to state. In former days engineering technology was founded chiefly upon current practise rather than upon established principles; it was more closely allied to the crafts than to science. Not only is that day past, but it is no longer the case that technical science looks entirely to pure science for its fundamental material. It has so grown that it is investigating for itself and, in greater and greater measure, developing the basal principles for its own needs. There are very few American treatises in pure science which will compare in scientific thoroughness with several treatises which have lately issued from the engineering press. This is a very hopeful sign in the growth of knowledge—to see applied

science and pure science approaching each other at numerous points, so that it is increasingly difficult to distinguish any line of demarcation between them. In this change, *science is not sacrificing any of its strength nor compromising its ideals.* It is *technology* that is changing—that is becoming less empirical, more systematic, more quantitative, more scientific.

With these well recognized changes in applied science before us, what should be our attitude toward the mathematical science that is necessarily associated with engineering education? What is technology really requiring of the basal sciences? Judging the engineers by their acts and not by their words, what is the real demand that they are making of the physicist, of the chemist or of the mathematician? Is the demand to teach physics or chemistry in this or that particular way, or is the demand of a profounder and more radical sort? The most superficial observation shows that the demand is of the latter kind. The engineer in this twentieth century is saying to the physicist, and chemist, and mathematician: "Know more science. Discover more facts in electricity—in light—in all properties of matter. Give to the world more men like Kelvin, Hertz, Helmholtz. Fill the shelves with ten times the knowledge we now have." These words more truly express the real pressure that engineers are putting upon workers in pure science, than do the words they have uttered in this discussion. As a single example, note that the great electrical and other manufacturing companies are impatient at the rate at which pure science grows, and large sums are spent by them each year in the search for new truth and in filling up the gaps in existing knowledge.

The real demand of the engineer is not for better instruments or tools with which to do his work, nor is the demand for more difficult projects to test his skill, nor even for more capital with which to construct them. The real demand is for more knowledge, more science, and for more of the spirit of science in technology and in technical education. I take as my text a saying of Ostwald: "*Science is the best technology.*" If we teach a trade and not a science the time is largely wasted. If we teach *dyeing* and not *chemistry,* the graduate is already out of date when he begins his career, and he has not the fundamental principles wherewith to bring himself abreast of the times. I therefore regard it of greatest importance that mathematics be taught to engineering students with real enthusiasm for the science itself. It should be taught by men who themselves are actively contributing to the growth of mathematical science. The present spirit of engineering science is such that no instructor in any of the basal sciences is satisfactory who does not see that it is his duty not only to teach what is old, but to be interested in and to take an active part in the development of what is new.

I regard of secondary importance the particular things we do in the mathematical course in the engineering school. Different instructors, equally successful, will have different opinions. Various changes and improvements have been tried at various institutions. At the University of Wisconsin we have made innovations whenever we thought it best, but I regard them all of secondary importance to the first requirement of all, namely, that we demand the right sort of teachers, and that the teaching be done in the right sort of scientific spirit.

The only imperative requirement put upon the mathematics in engineering schools that does not rest as heavily upon the mathematics of the ordinary college course is the demand for compactness. It is possible that there is some room in the

courses in colleges of pure science for the whims and fads of the various instructors, for at some later place in the course the balance may be restored. This, however, is not true in a school of engineering. There is very little room for the practise of fads and new schemes. It is easy to exaggerate the need of a special sort of subject matter in mathematics and a special class of problems for engineering students. We are apt to make some very foolish mistakes, if we undertake to change too freely the scientific material that is presented to engineering students. A good engineer is worthy of the best science and the best instruction that can be brought to him—he himself would be the first to object if a different program were carried out.

I have had a little experience in employing engineering graduates in engineering work. In the past ten years I have given employment, in various capacities, to about one hundred and thirty engineering graduates. This work has been scattered over quite a wide territory and the men have come from the institutions of the east, from the Pacific Coast, from the Mississippi Valley and from the south. I have been able to judge within the limits of my experience what the young engineering graduates know, and what they have forgotten. I find it true that the boys have forgotten a great deal of the material they had in college, and that they have remembered other things. They remember the manual and the mechanical things—how to swim, how to ride a horse, how to fish, how to play ball, how to run the level, how to work the plane table, and how to do stadia work. Now what have they forgotten? The men have forgotten the intellectual things—hydraulics, electrical science, thermodynamics, etc. The human mind possesses an unlimited capacity for forgetting. But my experience shows that the young men forget their hydraulics just as quickly as they forget their mathematics or their mechanics. The engineer in the field observes that a boy remembers the right end of an instrument and seems to be amazed that the same man does not know the right end of an integral sign. He therefore concludes that the mathematics has not been "taught right." If he will compare intellectual things with intellectual things he will find that a miscellaneous group of engineers will pass as good an examination in mathematics ten years after graduation as they would pass in thermodynamics or hydraulics.

It grates on me to hear mathematics spoken of as a tool. Mathematics is to the engineer a *basal science* and not a tool. The spirit of that science is of more value to the engineer than the particular things that can be accomplished. The engineer need not be a mathematician, but he needs to think mathematically, and, to my mind, he needs the power of mathematical thought more than skill in manipulating a few mathematical tools in mechanical fashion. There are already too many factory-made products turned over to the college by the secondary schools. I make a fundamental contrast between the engineer with his mind endowed with the power of creative and rational design, and the artisan with his hands equipped with tools for physical construction. A great engineer must be trained in correct seeing and thinking, and must have the power of reasoning concerning some of the highest abstractions of the human mind. In this aspect mathematics is not a tool—it is a basal science.

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At the close of Professor Townsend's address he urged the desirability of technical schools offering more elective ad-

vanced work in mathematics. It may not be out of place, therefore, for me to call attention to the fact that in the Massachusetts Institute of Technology we have offered and given, among others, the following courses: advanced calculus, vector analysis, fourier series, least squares, theory of surfaces, theory of functions, elliptic functions, hydrodynamics and differential equations of mechanics and physics. Some of these subjects are required in one or more of our courses, but not in any one of the larger engineering courses, which are taken as the basis of Professor Townsend's tables. This elective work, therefore, while valuable in many respects, is not the main work of the mathematical department.

The mathematical teacher is in the engineering school primarily to teach to students of engineering the amount of mathematics which is necessary to them for the proper understanding and practise of their profession. The object is to give the student a grasp of mathematical concepts and processes through their use, as one learns grammar by speaking a language. Hence there is no place in the required mathematics of a technical school, nor indeed in the first courses in a college of liberal arts, for the refinements of modern "rigor." At the same time there should be no patience with a loose or unscientific presentation of first principles. The teacher himself must be thoroughly conversant with modern thought, else he will teach falsehood for truth, and must be enthusiastic in his interest in his subject, else he will fail to inspire his pupils. Hence the teacher of mathematics should be primarily a mathematician and not an engineer. It is hard to find an engineer who has any knowledge of mathematics other than a small fragment which he habitually uses, and any elementary teacher whose instruction goes to the very limits of his knowledge is sure of failure. It may, of course, be possible to superimpose a mathematical training upon an engineering one, but in that case the engineer becomes a mathematician and my contention that mathematics should be taught by a mathematician is not invalidated.

On the other hand, the mathematician should know something of the uses to which an engineer wishes to put mathematics. For that reason such meetings as this are helpful, but I must confess to feeling a little disappointment in not obtaining from the engineers any new light on the concrete problem which confronts the teacher of mathematics in an engineering school. I have met the same disappointment elsewhere in similar meetings. It has happened, elsewhere if not here, that engineers will tell the mathematicians what and how they should teach, in apparently total ignorance of the fact that what the engineer promulgates as a new gospel has been the commonplace thought of the mathematician for years. This ignorance may be due to the fact that the engineer remembers his own training of twenty or thirty years ago and does not know that improvements have taken place. That such is the case may be seen by a comparison of modern with older text-books. Such criticism from the engineers is amusing, but another kind of criticism is not. I refer to the kind which seizes upon the failure of a student to have learned mathematics thoroughly as evidence of poor aims and inefficient teaching of the mathematical instructor. We all know that students pass through our classes and graduate from our schools whose attainments are not what we wish, but while the mathematical teacher delivers his product to the engineering departments and hears of his comparative failures, the engineering professor delivers his product to the world and rarely hears of the specific blunders of his stu-

dents. Another unfair criticism is sometimes heard from the professor of engineering who says that students can not use their mathematics, when the truth is they have simply forgotten some particular fact, formula, or process, which is a fad of that professor. It is unfair to test mathematical training by tenacity of memory or mere quickness in reasoning.

I have said that we must teach our students to use their mathematics. Now in the application of mathematics to a concrete problem there may be distinguished three steps:

1. The interpretation of the data of the problem into mathematical language.

2. The formal operations upon the expression or equations thus obtained.

3. The interpretation of the results back into the terms of the original problem.

The first and third of these steps are really the most important, but there seems to be a popular impression that the second comprises the whole of mathematics. This impression is doubtless responsible for some criticisms of the educative value of mathematics. It is true that relatively a great amount of time must be spent in the classroom in teaching the mechanical processes involved in the second step, and many students in school and college get no farther. To object to the amount of time spent in this way and to demand, as some do, that we confine our time to teaching general principles and applications is to talk as sensibly as a fond mother who objects to a child beginning his musical education by playing finger exercises instead of tunes. The technique of mathematics must be learned first, but the student who never gets beyond the technique has not learned mathematics.

The teacher of mathematics should, then, use all possible means of teaching the first and third of the above steps and should bring his pupils to think of them as the real thing. For that purpose he should seek for applications and illustrations from as wide a range of subjects as possible. He will find himself handicapped, however, in using many problems of real scientific or engineering importance because of the ignorance of his pupils, especially in the first year in the technical school. To illustrate a new mathematical principle by an application to a science with which a student is not familiar is to befog and not illumine the subject. Hence there is something to be said in favor of some of the much-criticized problems of the older textbooks. To my mind a problem is successful if it causes the student to take the three steps just enumerated and is couched in terms familiar to the student, even though it may not be "practical." On the other hand, a type of problem lately coming into use, in which the student is given some formula from a science of which he knows nothing, and is asked to find, say, a maximum value, is as fruitless as if the problem were stated in terms of x, y and z, unless it may serve to convince a sceptical student that the matter he is studying has some practical application.

And this leads me to the most important thing I have to say, and that is that after the mathematical professor has done his utmost to teach the use of mathematics the engineering professor must take up and complete his work. I doubt if any one really learned the use of mathematics in a first course. Facility in using mathematics comes from actual use and not from the solution of illustrative examples. In the course in mathematics the student expects his problem to be solved mathematically and has his mind alert to find the solution, and that too with mathematical principles fresh in his mind. In a course in engineering, his point of view has widely changed. The practical problem has now his main interest, mathematical concepts

are in the background, and he often fails to see the possibility of using mathematical principles until he is trained to do so by the professor of engineering. If the professor, through lack of knowledge or lack of interest, avoids the use of mathematics, the student will soon lose the little he has learned.

In other words, the mathematical training of a student is not complete when he leaves the department of mathematics. It is possible that better results could be obtained if the mathematical department had more time, say for a course in applications of mathematics to miscellaneous problems. But, as a rule, in our technical schools the department of mathematics is allowed barely time to teach the necessary technique with what illustrations and applications can be squeezed in. Hence the mathematical department delivers to the engineering department an unfinished product and it is the engineer's duty to teach the student to use the mathematics he has learned. Unfortunately, the professor of engineering is too often a poor mathematician and avoids this duty.

One of the hardest things a student has to do is to combine two different domains of knowledge, each somewhat unfamiliar, so that he may work freely in both at once, using each as a help in the other. It is this difficulty which makes analytical geometry traditionally hard, and which the student meets again when he studies any form of applied mathematics. It is partly to help overcome this difficulty that we have just made a rearrangement of our mathematical instruction in the Massachusetts Institute of Technology. We no longer have courses in algebra, analytic geometry and differential and integral calculus, but have combined these into one "course in mathematics" extending through two years. Into this course the elements of analytic geometry and of calculus are introduced early and continued late. We hope thus to give these principles more time to become completely domiciled in the student's mind. We have also been enabled to carry out two principles: the first is to introduce no subject until some use is to be made of it, and the second to handle each problem by the method best adapted to it, rather than by the methods of the particular branch of mathematics which one might at the moment be studying under the old classification. We hope in this way to increase the efficiency of our mathematical teaching.

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The program shows three standpoints from which discussion is to emanate. I occupy no one of them. It is true I have had some engineering practise, but I can not be termed a practising engineer. I have had charge of mathematics for engineering students in two engineering colleges, but for nearly a decade now I have not met students in mathematics; and, indeed, I have taught, all told, but an insignificant amount. I am in somewhat close touch with engineering students, but they belong to a particular field, namely, mining, which is possibly less dependent on mathematics than are other branches of engineering. My view-point is, therefore, somewhat of a compromise or average of the three specified in the announcement.

The present discussion seems to me significant. It may bring forth results. In fact it seems to have had some immediate consequences. Last evening after the dinner I heard a very clever mathematician admit that he felt really humble, and I heard a well-known engineer say that to his great surprise some mathematicians had a human side. I asked a pure mathematician sitting near me to show me his hu-

man side, but he only shrugged his shoulders. Perhaps he was not yet sufficiently humbled.

This occasion appears to me to be significant, but as showing conditions which exist rather than as forecasting future changes. It is a symptom of the approach—the arrival, perhaps—of healthful conditions rather than a cause. It may, of course, in its turn become a cause, and operate toward good results. That is not so certain. At the moment it indicates conditions surrounding the teaching of mathematics to engineering students, including the relations between the teachers of mathematics and those of engineering which have been the growth of many years. Those young and virile gentlemen whom we all delight to honor, the Woodwards, have been striving for decades to bring about a closer relation between the teaching of mathematics and the subsequent study of practise of engineering. Ten years ago at the Toronto meeting of the Society for Promotion of Engineering Education I presented a paper looking to this end.[2] There are gentlemen here present who discussed that paper and who may perhaps recall the remarkable unanimity between the teachers of mathematics and those of engineering as to the results most to be desired in teaching mathematics to engineering students, and, indeed, as to the best available methods for producing such results. This movement is old. Most of the ideas which have been brought out here were first conceived a long time since. Nevertheless, it is good to get together and talk them over, and such discussions may result in help to the individual teacher.

We have heard here much of the ideal which the engineering school should set before itself, but it might well be asked what problem is presented first to the school as a matter of fact? President Woodward put it in part when he spoke of the difficulty of getting the right men in the schools when operators are so eager for good men and are competing on the basis of "so much per month." And what do the employers demand? They call for men who can do something, men who can think in a logical and common-sense way, but, withal, when they leave the school can be put to some immediate use. The first problem confronting the engineering college is how to meet this demand, for the demand must be met in some degree at least or the college will cease to train men.

It is inevitable that the character of this demand shall influence largely what the school must do. The call is not for men highly trained in mathematics, however much we may feel it ought to be. It is for men who know well a little mathematics, and who can do something with it, who can use it "as a tool." And, however obnoxious that expression may be to a mathematical teacher, he who forgets or disregards the fact which lies behind it will surely weaken his instruction of engineering students.

I do not defend the specification of the employer, I point to the fact with which we must deal. Personally I am inclined to find fault with it, but the matter rests largely in the hands of the practising engineer. He, though he often objects to the college product, is to a great extent responsible for its general make-up. In the long run and within reasonable limits he can have what he wants. Sometimes he is inclined to require too much technical knowledge on the part of the graduate. His brother teaching in the college in order to meet his requirement says to the teacher of mathematics I must have those students ready earlier with their mathematics. This fact, together with the general tendency in the colleges to raise the standards, causes

[2] See *Proceedings* of Society for Promotion of Engineering Education, Vol. V., 1897, p. 139.

the mathematical training to be crowded into the first year and a half or two years, when the student is least mature. More of it is being pushed back to the secondary school, and, in turn, into the grades. Mathematical concepts are difficult, and with President Woodward I am inclined to think we are demanding too much, and calling for it too soon. Covering less ground and at a slower pace will help to make better engineers.

The student comes to the engineering school with the notion that he is to be filled up with a lot of technical knowledge, the items of which will be used by him when he is a practising engineer. He seems unable to comprehend that he is in college to acquire mastery over his own powers. He is eager for useful facts and of course he forgets most of those he learns not a great while after leaving college. The forgetting is to be assumed. Under such conditions the task before the teacher of mathematics, and quite as well before the teacher of engineering, is to do his utmost to train his student to think logically and accurately about things. To this end there seems to me nothing so efficient as the solution of a large number of carefully chosen problems. Indeed what is one's life, if it be active, except meeting a never ending succession of problems which must be solved if success is to be gained? If you can teach your student to take vigorous hold of a problem, to first assemble all the facts which bear on the question, then from the facts to reason logically to a sound and safe conclusion, you have started him well whether his aim be engineering or otherwise.

Of transcendent importance is the teacher, his personality, his attitude toward his work, his knowledge of his students, not as a class, but of each as a human being. If we can procure the teacher who can idealize his work, who can show sustained enthusiasm for it and perform cheerfully the drudgery we heard mentioned a few minutes ago, we can safely leave detailed methods to him. Whatever methods such a man adopts in the classroom are likely to be effective.

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Michigan College of Mines

THE BRITISH MUSEUM OF NATURAL HISTORY

On July 28 a deputation, which included Mr. F. Darwin (Cambridge), Professor Cossar Ewart (Edinburgh), Professor Sedgwick (Cambridge), Dr. Marr (Cambridge), Professor Hickson (Manchester), Professor Bourne (Oxford) and Professor Graham Kerr (Glasgow), waited on the Prime Minister (Rt. Hon. H. H. Asquith, K.C., M.P.) in support of a petition sent to the late Prime Minister last autumn requesting that advantage should be taken of the present vacancy in the directorship of the Natural History Museum to hold an inquiry into the methods by which the museum is governed. The deputation was introduced by Sir W. Anson, M.P., Mr. Rawlinson, M.P., and Sir H. Craik, M.P.

According to the account in *Nature*, Professor Sedgwick said that zoologists thought it desirable to at once call the attention of the government to the desirability of instituting an inquiry into the methods of administration of the Natural History Museum, and that, if necessary, a widely signed memorial could be sent later on. In concluding a very full statement, Professor Sedgwick said:

> We are here to ask for a full official inquiry into the organization and administration of the Natural History Museum with a view to a reasonable treatment of the matter in the immediate future by his majesty's government.

Mr. Francis Darwin especially referred to the subordination of Cromwell Road to Bloomsbury. He said:

> Quite apart from the welfare of the Natural History Museum, it seems unfair to expect of the principal librarian that he should be responsible for Cromwell Road in addition to his other heavy